

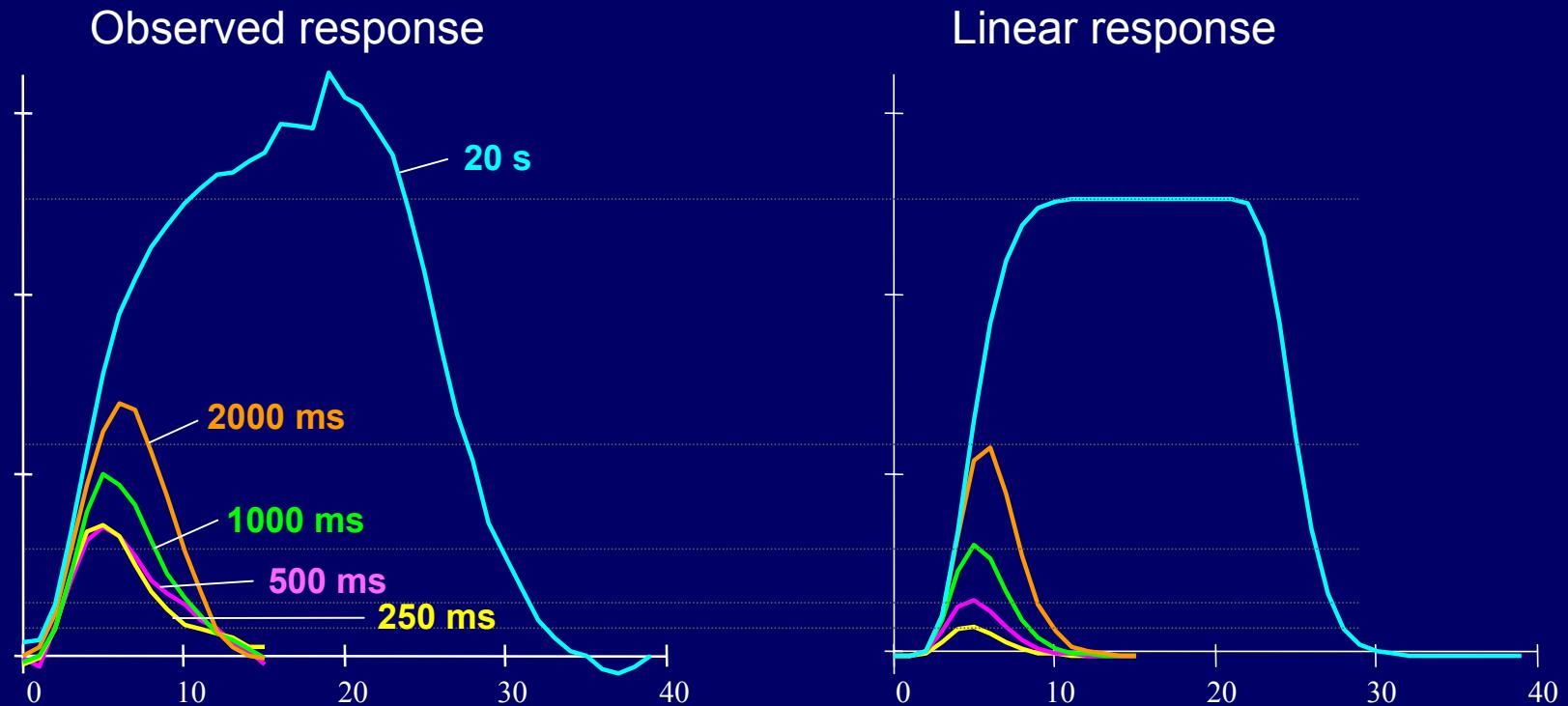
Spatial Distribution of the Nonlinearity of the BOLD Response

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BOLD response is nonlinear



Short stimuli produce larger responses than expected

Background

- Nonlinearity: neuronal or hemodynamic ?
- Flow is linear, BOLD is nonlinear
 - *K. Miller, et al., Proc. ISMRM 1999, p. 381*



Nonlinearity of BOLD \leftarrow hemodynamics (flow \leftrightarrow BOLD)

If nonlinearity is hemodynamic in origin, a measure of this nonlinearity will reflect any spatial variation of the vasculature

Model

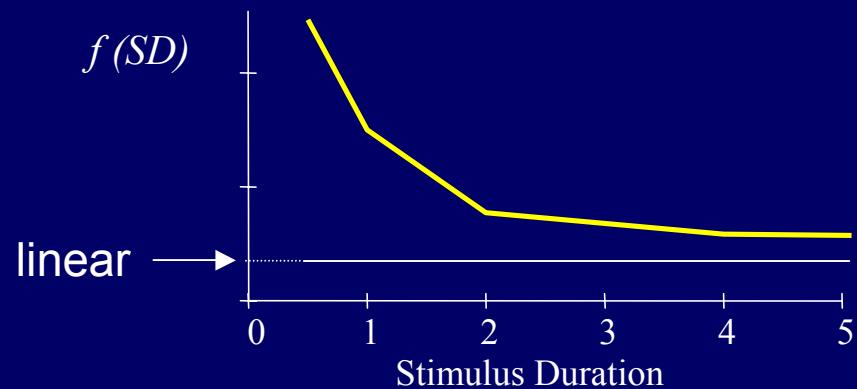
Linear

$$s_x(t) = \alpha_x r(t) + \text{baseline} + \text{noise} \quad r(t) = \text{stim}(t) * h(t)$$

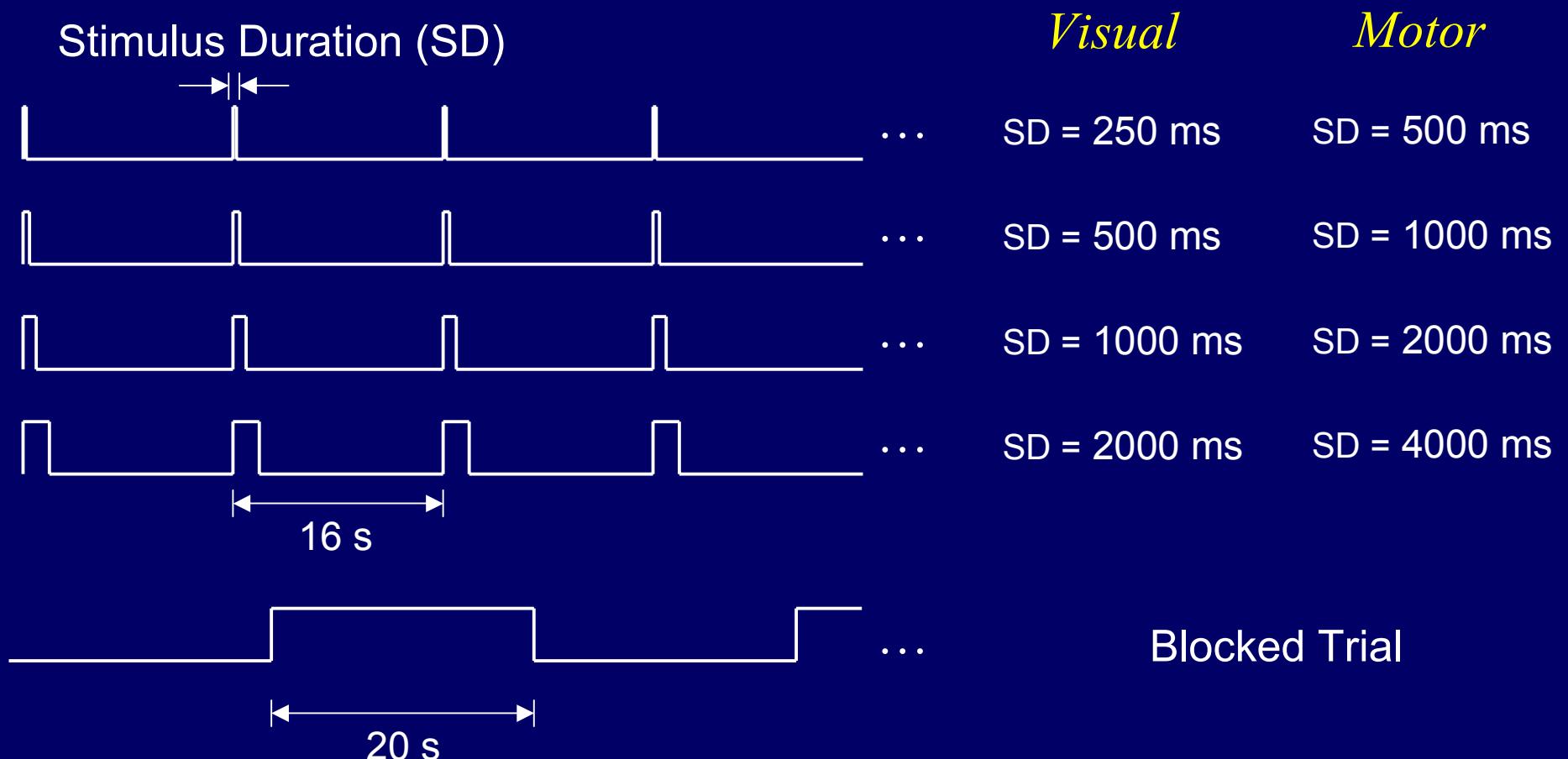
Non-linear

$$s_x(t) = [\alpha_x f_x(\text{SD})] r(t) + \text{baseline} + \text{noise}$$

amplitude *nonlinearity* *ideal response*



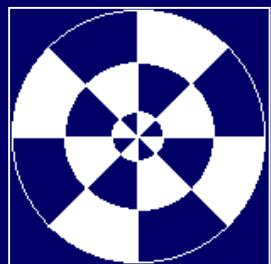
Methods



Methods

Tasks

Visual Stimulation



Finger tapping

Cued by light

500 ms, 1 s, 2 s, 4 s, blocked-trial

Imaging Parameters

3T

EPI

64x64

24 cm FOV

5 mm slice thickness

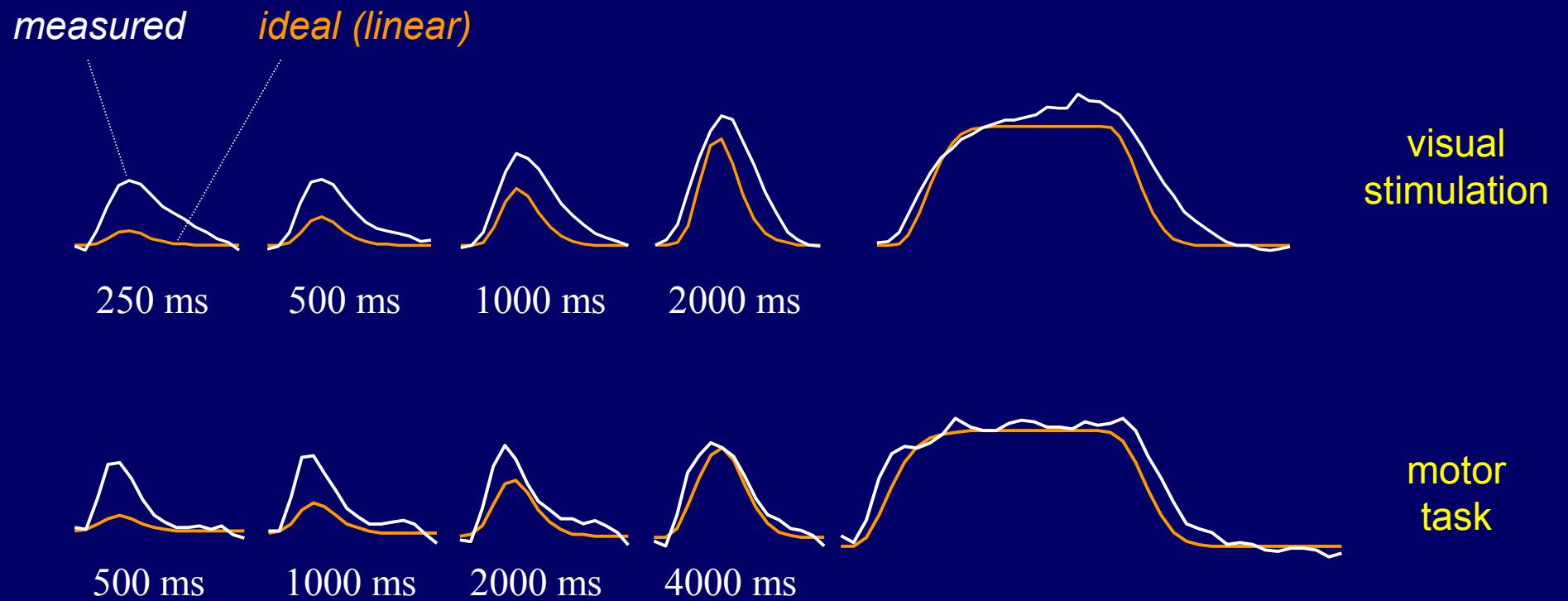
8 slices

TR: 1000 ms

TE: 30 ms

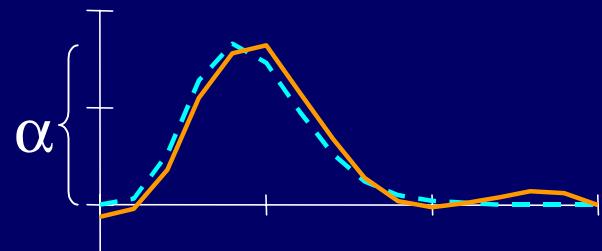
320 time points

Observed Responses



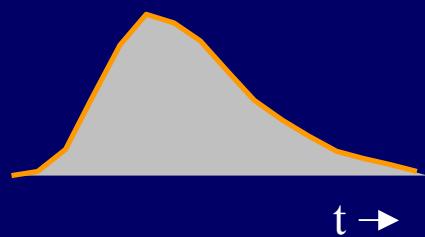
Compute nonlinearity (*for each voxel*)

- Amplitude of Response



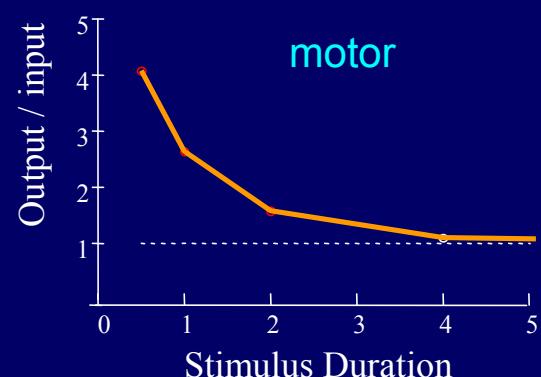
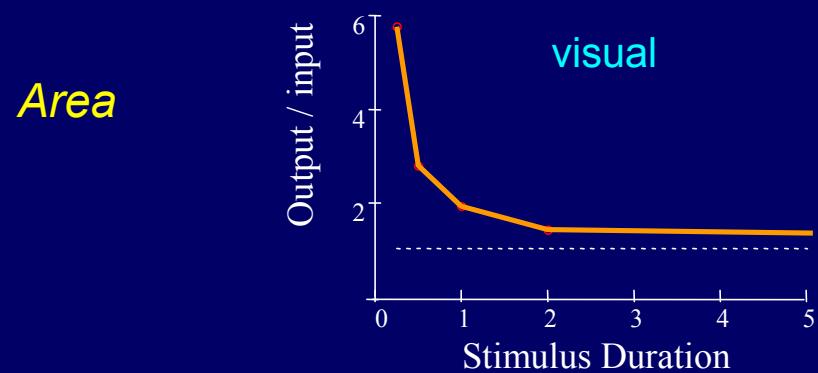
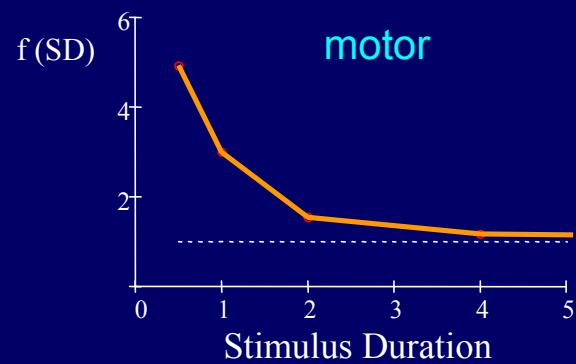
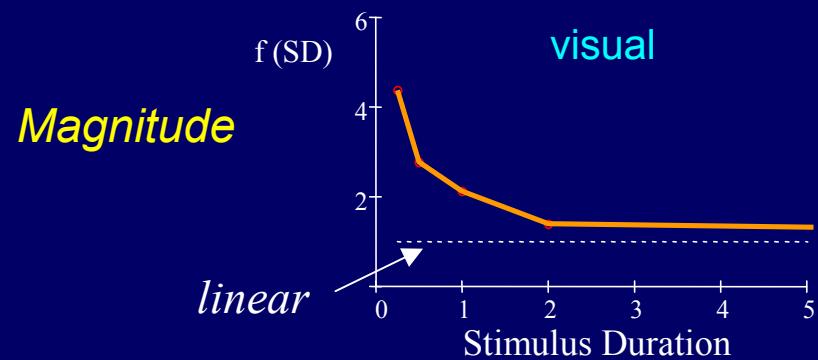
Fit ideal (linear) to response

- Area under response / Stimulus Duration



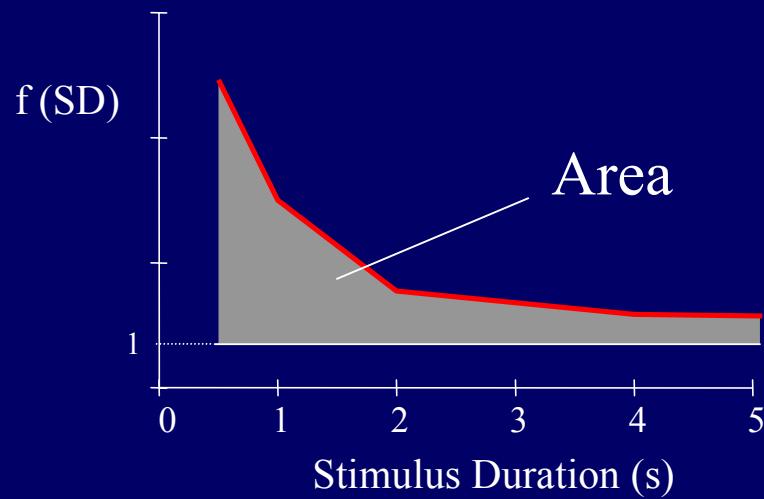
Output Area / Input Area

Nonlinearity



Measure of Nonlinearity

- Area under nonlinearity curve

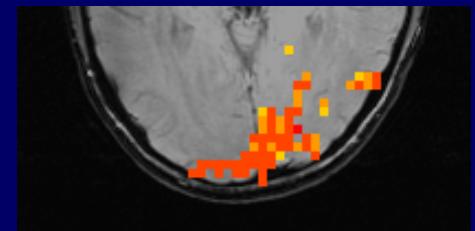
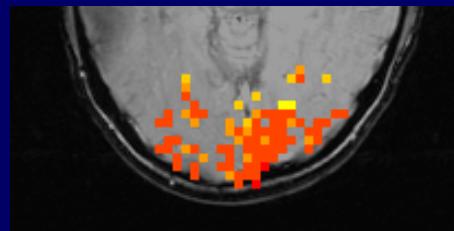
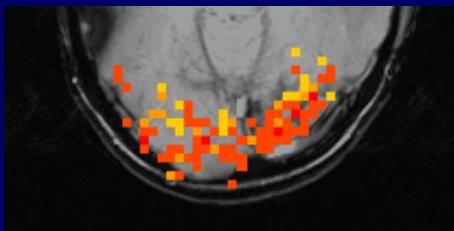


- Slope of nonlinearity curve

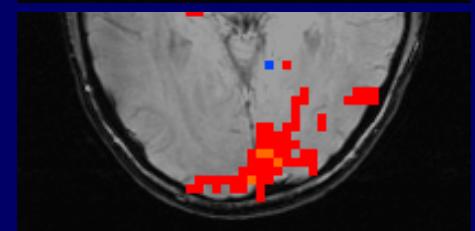
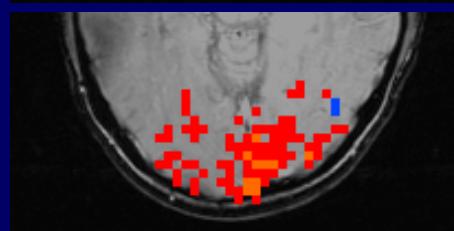
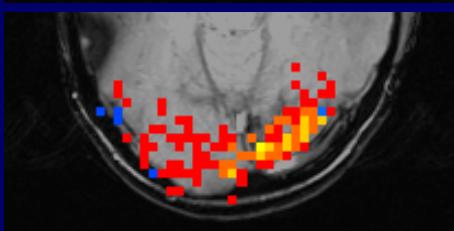
difference at each SD

Results – visual task

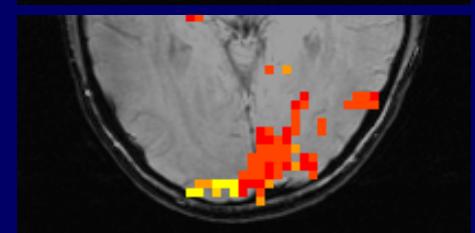
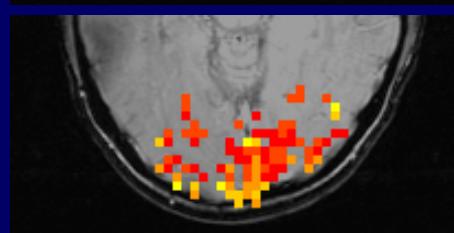
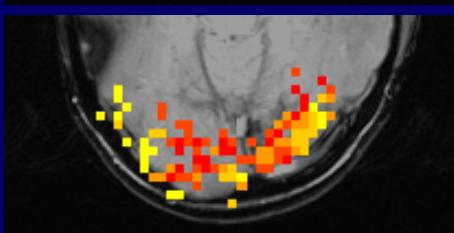
Nonlinearity



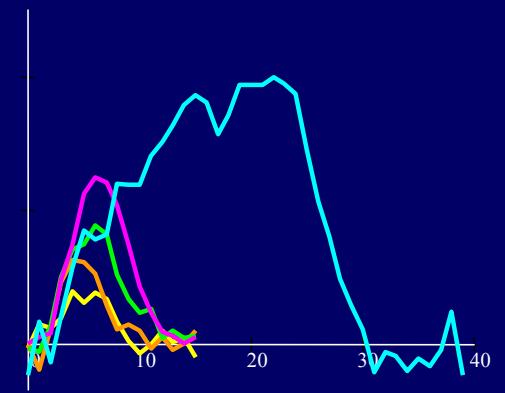
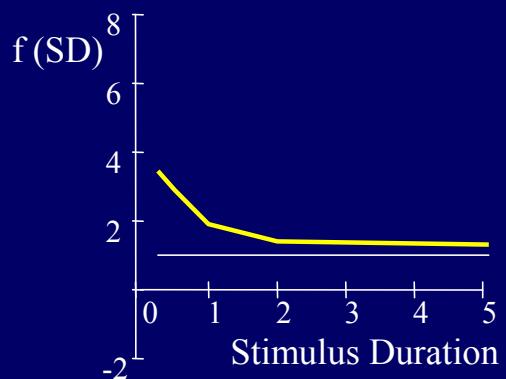
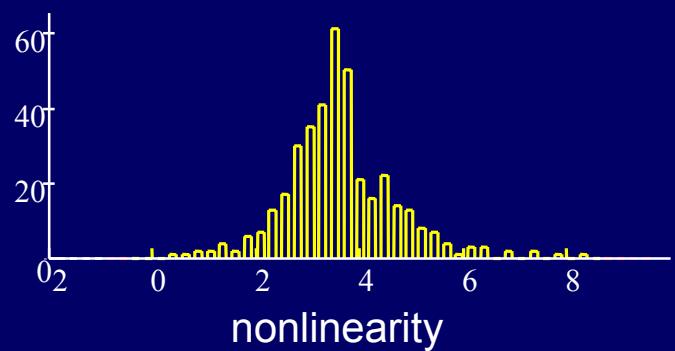
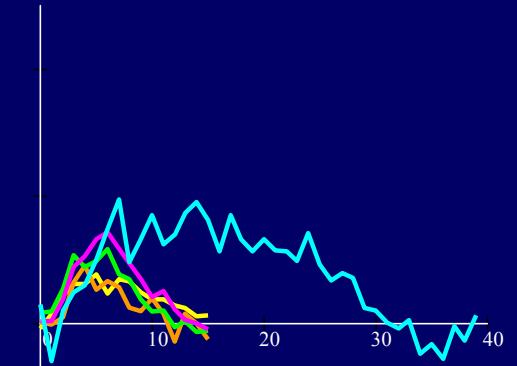
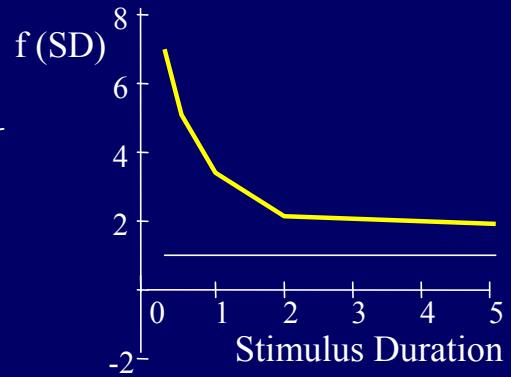
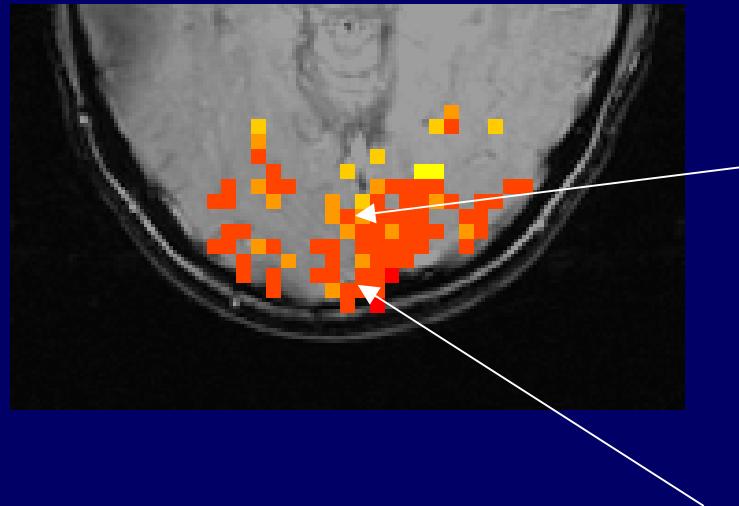
Magnitude



Latency

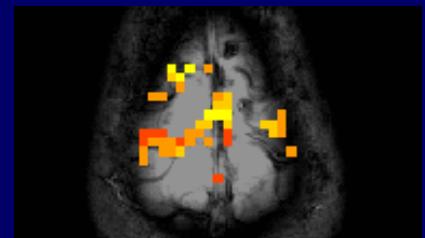
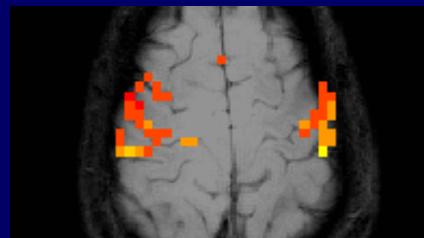
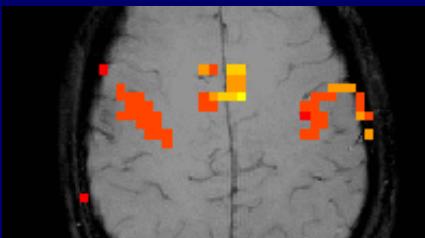


Results – visual task

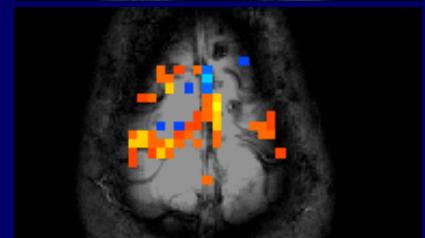
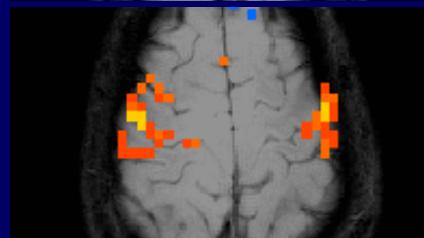
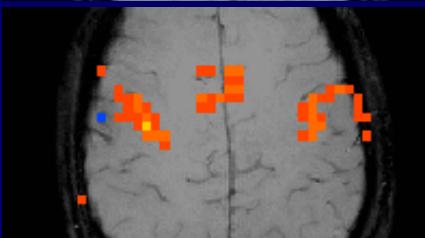


Results – motor task

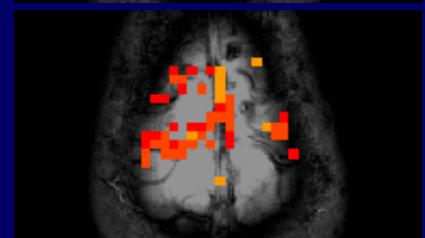
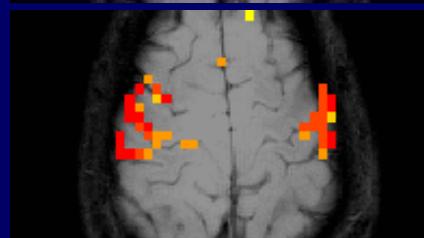
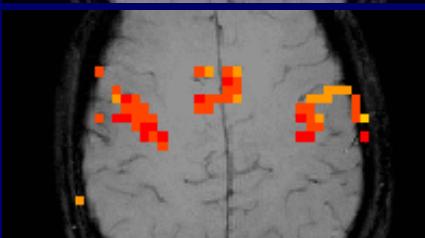
Nonlinearity



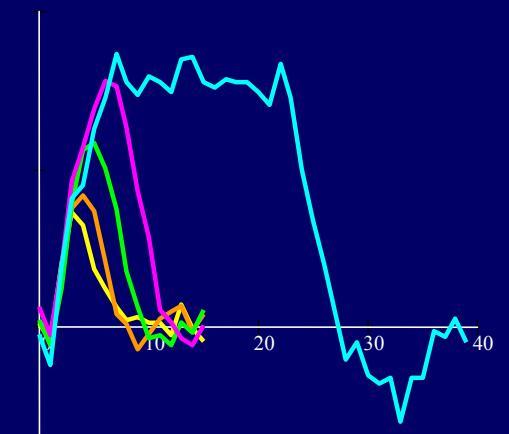
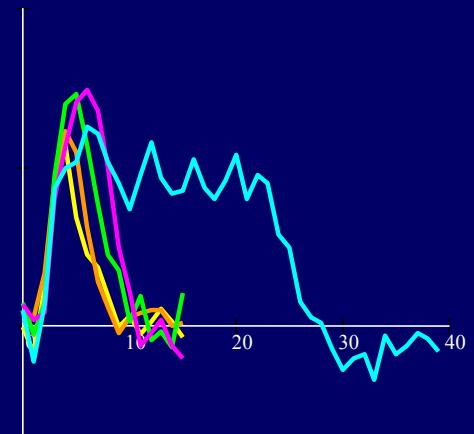
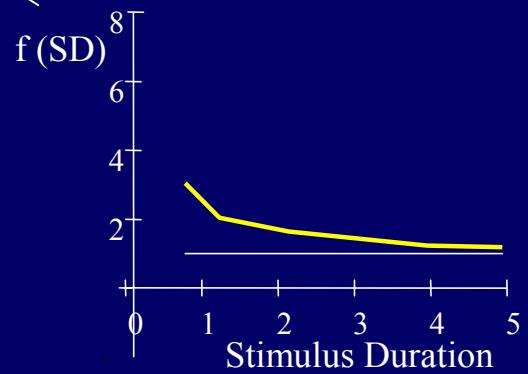
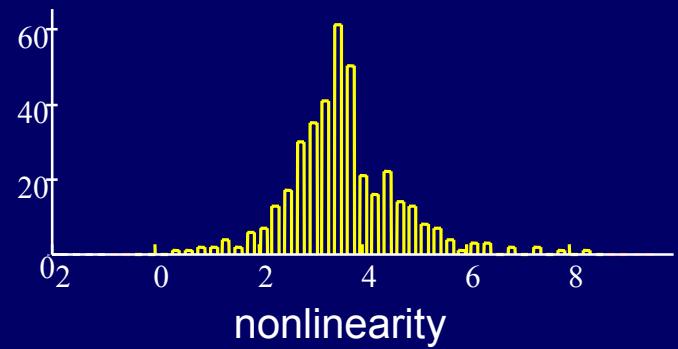
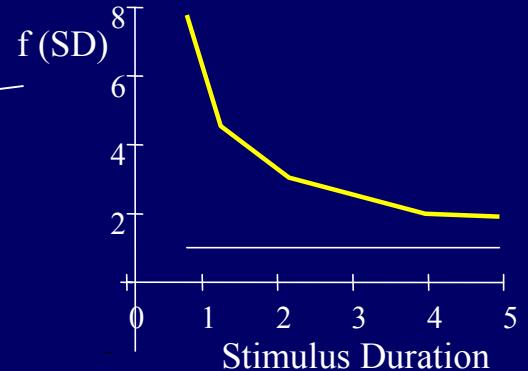
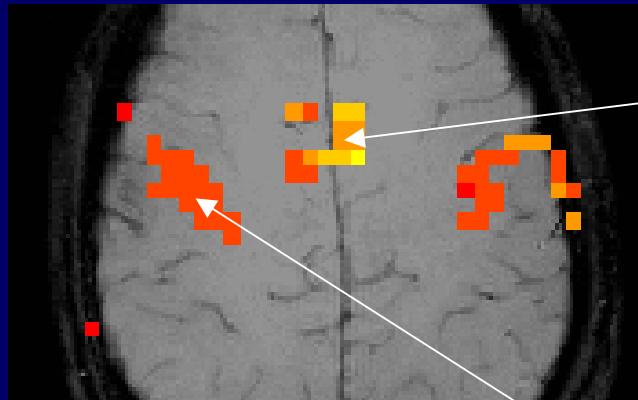
Magnitude



Latency

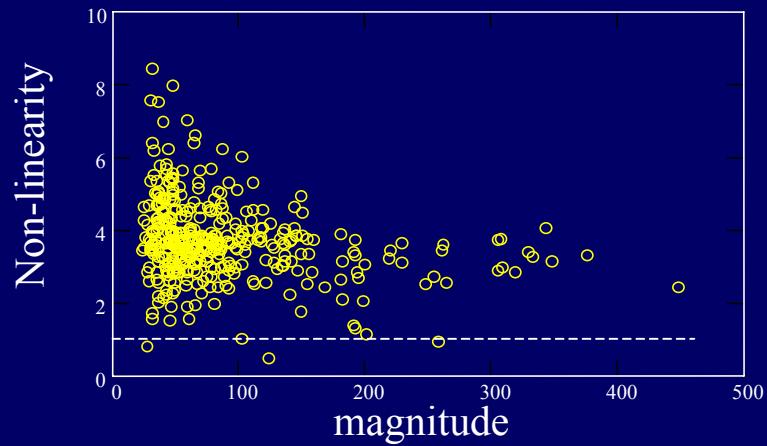


Results – motor task

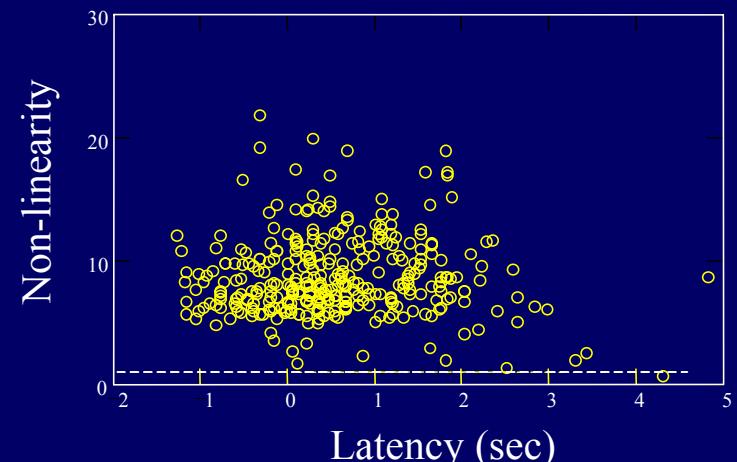
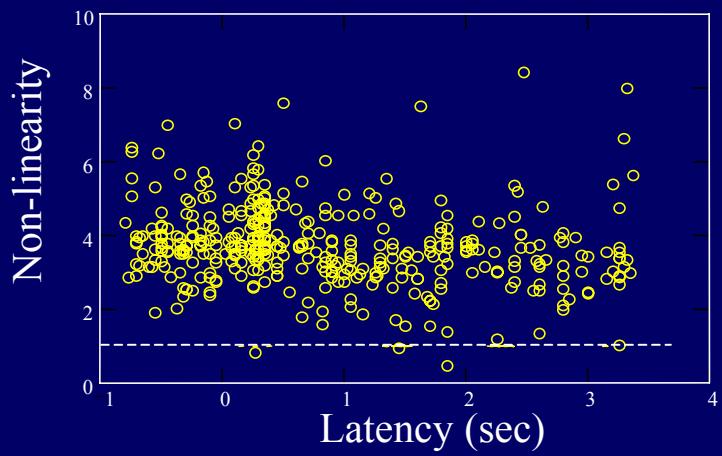
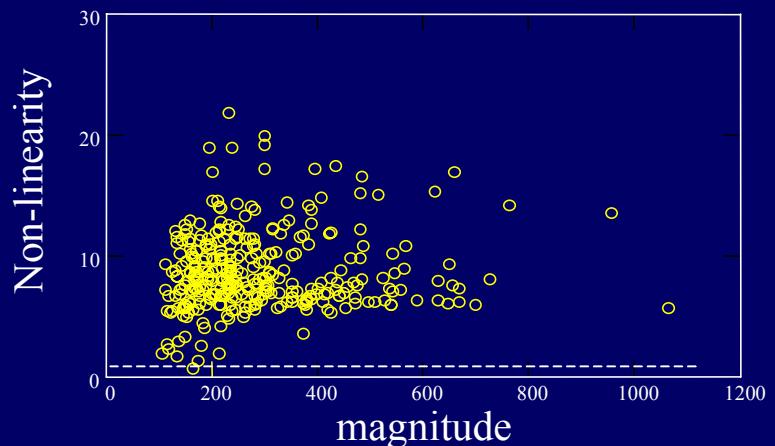


Correlation: Nonlinearity vs. Magnitude / Latency

Visual task

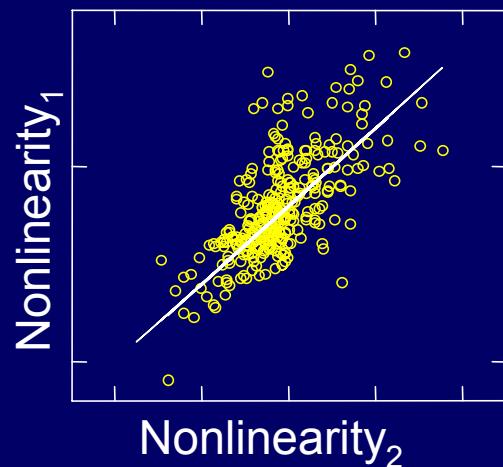


Motor task

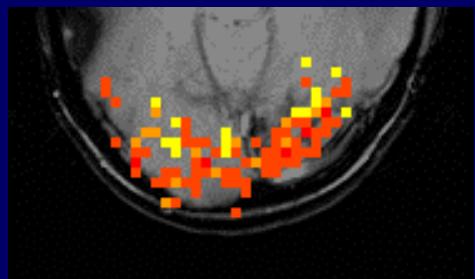
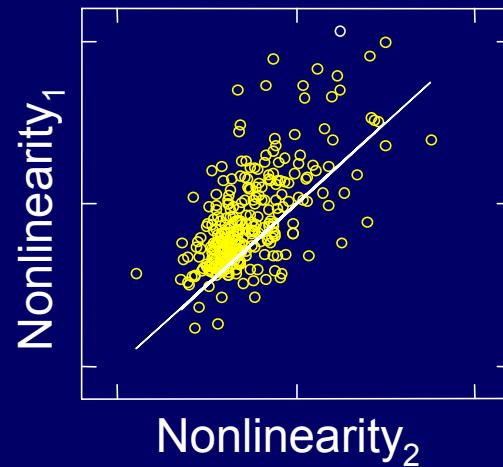


Reproducibility

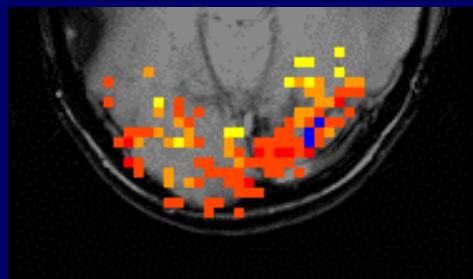
Visual task



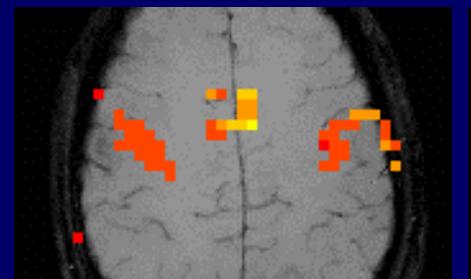
Motor task



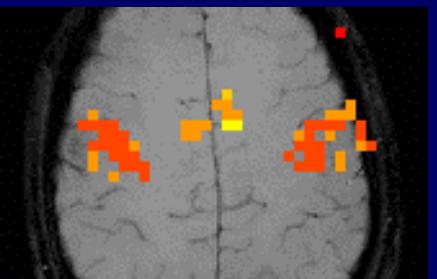
Experiment 1



Experiment 2



Experiment 1



Experiment 2

Conclusions

- Responses to short stimuli are larger than predicted from a linear system
- Spatial variation in this nonlinear relationship was seen
- The variation in nonlinearity was not significantly correlated with magnitude or latency